# Choosing the right low power processor for your embedded design

## Key selection criteria show where various low power processors best fit

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In early days, getting a lower power CPU typically meant sacrificing functionality, running at reduced clock speeds, or waiting for new low power process technologies to reduce both **Standby** and **Active power**. This is no longer the case by any means, and the processor landscape has changed dramatically.

Advances in processing technology along with innovative chip designs and high-granulation power management software have brought entirely new families of low power processors where designers no longer need to make sacrifices in their system designs.

Of course, no one device "has it all," so engineers must consider their system requirements carefully and then examine the now expanding range of low power processors to see which one best fits their application requirements.

This article summarizes the state of the art with a product-selection matrix (Table 1, below). One axis shows the following design criteria that are of chief concern to system designers:

* Power
* Performance
* Integration
* Time to Market
* Price

The other axis lists the major processor variants based on their feature sets. This article then explains the meaning behind the generic criteria and how various types of processors earn their rankings in the table.

**Table 1: Decision Table for Designers Selecting a Low Power DSP**

| | Power | Performance | Integration | Time to Market | Price |
|---|---|---|---|---|---|
| ARM + DSP (Floating-point) | excellent | good | good | excellent | good |
| ARM + DSP (Fixed-point) | excellent | good | good | good | excellent |
| ARM + audio coprocessor | excellent | fair | good | excellent | good |
| ARM-only | good | fair | fair | good | good |
| High-performance DSP (Fixed-point) | excellent | good | fair | good | excellent |
| High-precision DSP (Floating-point) | excellent | good | fair | excellent | good |
| Low Power DSP + coprocessor | excellent | fair | excellent | good | good |
| High-performance ARM + DSP + Coprocessor | good | excellent | excellent | good | fair |

This information achieves two goals: first, it alerts system designers to the newest types of processors on the market, some of which are relatively new and about which they might not be familiar; second, given this ever larger product palette, it helps them narrow down the selection of the best chip for a given design.

### Examine the criteria

To help you sort through the various low power devices, refer to Table 1, which grades the major types of low power processors according to several criteria of interest to designers. The first thing to note is that these criteria are all closely interrelated.

For instance, integrating a large number of functions on a chip such as multiple cores, analog features, large memories or many peripherals can reduce overall system power, cost and time to market. Extensive integration of this nature, though, can add unwanted power consumption and make programming more complicated, thus extending time to market.

**Criterion #1: Power**

For many of today's designs, this is the single most important criterion. In portable products, extended battery life is a big consumer plus. In many infrastructure applications, lower power translates to less heat dissipation " and heat-dissipation "envelopes" can be the limiting factor for channel density or feature additions.

There are also designs with a power budget such as USB-operated products or automotive aftermarket products running from a car battery that are allocated only a certain milliwatt budget for operation.

Power should be more properly viewed from a systems perspective. The right mix of peripherals on a chip results in more overall system power savings not only because off-chip devices consume extra power, but also because it takes a lot more power to move data across traces on a PC board than it does to move data within a device itself.

For individual devices, energy efficiency starts with the inherent benefits of process technology, but this is only the beginning of

what advanced processors offer in this regard. Power consumption can be broken into two main modes: first, active power consumption, which is performed with transistor switching and takes place during ongoing data processing; second, static power consumption, which takes place when either limited or no data processing takes place and various components go into a type of Sleep mode.

Several techniques are used within active power management:

***** ***Dynamic voltage and frequency scaling* *(DVFS).*** Here, clock rates and voltages are lowered by software command depending on the performance required by the application scenario.

For instance, even though the ARM on a multimedia processor might be able to run at 600 MHz, all that power is not required in every case. Instead, software can select from predefined operating performance points that run the processor at specific rates.

***** ***Adaptive voltage scaling (AVS).*** This is based on the fact that silicon manufacturing yields parts with a distribution of performance capabilities; for a given frequency requirement, some devices (known as "hot" devices) can achieve that level of performance with a lower voltage than can "cold" devices.

In this situation, a processor senses its own performance level and adjusts voltage supplies accordingly to compensate for variations in processing, temperature and silicon degradation.

***** ***Dynamic power switching (DPS).*** This determines when a section of a device has completed its current tasks, is not needed at the moment, and puts it into a low power state. An example of this granulated power control is when a processor enters a low power state while waiting for a DMA transfer to complete.

Static power management takes place when either limited or no data processing occurs, selected components can drop into a very low power mode, and where the system waits for a wakeup event.

Handled by a technique known as static leakage management, it can result in several low power modes from Standby to full Power Off. The choice of which low power static mode is chosen depending on what degree of memory retention and/or a fast wakeup time is needed.

Thanks to these features, most low power processors spec a standby power in the range of 15 mW and a peak operational power below 400 mW. However, some **fixed-point digital signal processors** drop those figures to 0.50 mW standby and 75 mW peak even though it contains a FFT coprocessor, as much as 320k bytes of memory and I/O peripherals.

In the table, most of the devices implement many if not all of these power-saving features and get an "excellent" rating. The ones listed as "good" are the highest performing chips, generally with multiple cores, which naturally draw somewhat more power.

**Criterion #2: Performance**

This criterion is important because added processing capability often differentiates end-user products by enabling new functions as well as more channels per cost or area, faster datarates as well as denser and higher-quality compression schemes.

In looking at performance, engineers should look beyond MHz and also consider parallelism. A big performance boosts come from chips that integrate a DSP, ARM or coprocessor in various combinations, an example being the **OMAP platform**. Engineers can thus partition their code to run on the most appropriate core.

Parallelism is a benefit you can get even on a device with just one core. For instance, a single CPU in **low power fixed-point DSPs** have extremely high processing capabilities thanks to eight instruction units that run in parallel at 300 MHz. For the same low power budget, the device offers 2X the processing capabilities as other low power processors on the market.

Besides integrating processing elements, integrating other system components can lead to considerable performance improvements. For instance, having sufficient on-chip memory means that a CPU can run code much faster than if it had to import and export data more frequently.

No matter what kind of system in development " whether multimedia appliances or those that have limited functionality but need the lowest possible power " designers can choose a processor with exactly the amount of processing power they need.

In the table, the range of performance going from "fair" to "excellent" is generally a function of how many cores and on-chip peripherals a given device has. As always, one tradeoff for performance, though, is typically power consumption.

**Criterion #3: Integration**

Clearly this aspect is closely related to performance. As just noted, certain chips offer designers the choice of either or all of the following on the same chip: DSP, ARM9 or a coprocessor.

With regard to integration, though, other essential system components can fit on today's devices. A good example is integrated memory, which lowers total system price, saves system power and eases development. Some low power processors incorporate

almost half a megabyte of memory directly on the chip, such as in the OMAP-L1x applications processors, and in many cases this eliminates the need for any external memory.

Today's processors, however, can integrate a much wider range of peripherals, including analog components. A prime example is an SAR (successive-approximation register) A/D converter. SARs are useful, for instance, for interfacing to touch-screen displays common in consumer appliances.

Another example is a uPP (universal parallel port), which allows direct connection to a wide range of other parts on a system such as high-speed ADCs or FPGAs. On today's low power processors you can also look for on-chip support for networking with Ethernet MACs, USB 2.0, Serial ATA (SATA) for mass storage, SDIO for I/O functions like WLAN support, LCD controllers, and video-port interfaces.

In the table, a rating of "excellent" refers to devices that have multiple cores or a coprocessor as well as a variety of peripherals; the "good" rating applies to devices with a single core but large amounts of memory and peripherals; a "fair" rating goes to devices that have fewer peripherals but that are power stingy and less expensive.

**Criterion #4: Time to Market**

This aspect is taking on ever greater importance as the rate of innovation in consumer products continues to increase and product life cycles are shrinking from years to months. No sooner is your latest, greatest product on the store shelves when a competitor brings out something a few months (or weeks) later with significant new features that draw consumers' attention.

Time to market is related closely to the level of integration. Obviously, if components are on-chip, engineers require less development and debugging time because there is no need to develop the interfaces and data-exchange facilities necessary to coordinate the activities of multiple chips. There is also less effort required in dealing with pc-board interconnects and working with separate drivers.

When many cores or peripherals are integrated on a chip, however, engineers need the proper software tools to help them manipulate the components. For instance, with a combination of an ARM and a DSP, a good toolset will allow the development of applications that need the resources of both cores but within a single programming environment.

In addition, engineers should also look to see what other tools the processor vendor offers in terms of third party algorithm libraries optimized for the various cores, support for third party tools such as Simulink from Matlab or LabVIEW from National Instruments, evaluation/development boards and even a variety of operating systems, even open source options. All of these factors are important in reducing development time and getting products to market on or before deadline.

A final aspect not to be forgotten is that **floating-point DSP devices** are less complex to program. In many cases, developers can write their code on desktop PCs using familiar tools such as Simulink and LabVIEW and then port the code to the DSP with very little modifications needed, if any.

In general, though, it is safe to say that the higher the performance on a given chip, the longer the development time. For the more-complex products that require this level of performance it obviously takes a longer time to develop and debug the code.

Finally, engineers should always be thinking ahead to the next generation of their products. In some markets, standards are fluid, but companies want to get an early jump into the market. Thus, designers must build "future proof" products that can be upgraded to reflect changes in standards or add new features.

It's thus important to look at a family of processors and examine its intercompatibility both in software and pin-for-pin compatibility " if I need more computational power, can I later add it with only very minimal changes to the overall system design and code?

In the table, a rating of "excellent" applies to devices with broad support in both hardware and software. A "good" rating goes to devices with a lower level of integration, meaning a few more off-chip peripherals or memory and the associated design effort.

**Criterion #5: Price**

When evaluating this criterion, engineers should look beyond chip prices, which themselves are dropping such that most low power processor now generally cost below $15, and depending on device features prices can drop to levels even as low as $4.00.

While the cost of each component is critical in consumer applications, it plays less of a role in infrastructure or commercial applications where the cost of ownership and efficiency tend to command more attention.

Engineers should rather consider total system cost. For example, returning to memory, if you can run all of a product's algorithms from on-chip memory, you've saved a dollar or two just for those extra memory chips that are no longer needed.

Significant system savings (up to $9.00) can be saved on integration combinations such as SATA, Ethernet, memory, USB 2.0, the ARM9 seen in the OMAP-L1X applications processors and other highly integrated peripherals mentioned in the Integration section.

Besides the price of chips, engineers should also evaluate ease of development, an aspect that encompasses software and

hardware development tools, technical support, training, third party support, documentation, engineering time/overhead and NRE development expenses. The bottom line is that faster development can lead to higher quality end products because valuable time and money are spent on differentiation rather than building the design infrastructure.

Thus, engineers should also consider not only the price of development boards and emulators but also their quality and how much they can speed development projects. High-quality IDEs and compilers give designers more visibility into their design and reduce time to market.

Look for silicon vendors who offer royalty-free operating systems, off-the-shelf verified code from third parties such as the codecs used in DSP-based designs as well as frameworks that allow designers to get going quickly on their designs.

In addition, don't forget the cost to layout and manufacture the board. Not only is the number of devices important, so is the pitch of devices " small-pitched devices are more expensive to lay out and manufacture at the system level.

In the table, price is generally inversely proportional to the number of cores and on-chip peripherals. The more such components, obviously the more expensive the device and the design effort because these are targeted at the most sophisticated portable systems. For example, the only category that gets a "fair" rating is the high-performance application processor that can have a DSP, an ARM and a coprocessor.

### Low power applications

Even with the help of this table, it's not easy to select the best device for a given application. There will always be design tradeoffs. But a brief discussion about application requirements might provide some guidance. Applications that require low power consumption have greatly expanded, and it helps to categorize the major areas:

* Products that are plugged in or USB powered such as a hands-free car kit, GPS dongle, touch screen or a speakerphone

* Applications where consumers expect batteries to last at least a full day such as a wireless microphone, musical instruments, noise-reduction headphones, wireless printers, and even multiparameter portable medical instruments

* Applications that should allow a battery lifetime of up to two weeks, such as a music recorder, e-book, door-lock fingerprint authorization or single-parameter portable medical instruments

Another way to categorize applications is by separating them into groups based on functionality. One concern is high precision in a portable device, such as in a musical instrument or audio product that requires a high dynamic range. This level of precision and dynamic range typically requires a **floating-point processor** , which has power consumption from 15 mW.

Now consider applications that rely on a feature-rich GUI. Here, a device that offers ARM-based processing is a good choice. Thanks to the ARM + DSP integration on devices such as the OMAP-L1x applications processors, there is plenty of capacity to run the GUI as well as handle sophisticated processing tasks.

Then there are products where consumers demand long battery life in a portable device, among them being portable audio recorders/ players, e-books, portable microphones or even home medical monitors that fit on the wrist. Processors that focus on low standby modes can enable weeks of battery life through high utilization of deep sleep (6.8 microwatts) and standby states (0.5 mW).

**Summary**

As stated often in this article, all of the selection parameters for a low power processor are closely interrelated. It's always been a case of the highest performance implies the highest power consumption " except today power levels have dropped across the board to where you can find a low power processor for virtually every need.

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